

®

RUBBER

Plantation

Manual

....A Guide to Rubber Plantation....



FALADE FEMI .A.

Acknowledgement

I ascribe all glory and honour to Almighty God, who not only give me the grace to produce this but also make provisions may His name be praise forevermore. Amen

To the glory of God this rubber plantation and production manual is compiled through several research both practical and theory to provide an answers to peoples questions on the plantation of rubber.

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Introduction

Rubber is an **economic crop** and one of the most important Cash crops in the rainforest agro ecological zone of Nigeria.

The crop has attracted a lot of attention recently As a result of growing uncertainties in the national Income as a result of over dependency on oil and the Current attractive prices of the crop in the international Market.

Rubber is a major source of employment opportunity especially for the restive youths of the Niger delta region Rubber belt of Nigeria covers land area of about 7.6 Million ha of land that lies in the southern part of Nigeria Extending from **Ogun State to Oyo, Osun and Ondo State**.

From the little experience we had in rubber plantation especially in the western region that is Ibadan We have succeeded in planting of an Acre of land at Ayede Erumu, which was growing well, also one Acre at Ada Village Olurundaba, Ibadan..2012 also a project is still going on at moniya Ibadan, we are making a ground for wealth for people who are ready to invest their money in a lucrative business. Research as shown that in the next 4 to 5years Rubber demand will persistency rise to a pick that the demand will be more than supply due to increase in the use of Latex in manufacturing companies and low Rubber famers.

Apart From rubber cultivation, the land is also utilized for the Cultivation of other crops, mining and urban development The soils of the area are predominantly coarse textured ultisols And oxisols derived from Cretaceous sandstones and Pleistocene unconsolidated Coastal sediments characterized by high Acidity, low nutrient status, low activity clay and are Subjected to rapid fertility decline on land clearing for cultivation Therefore, economical and sustainable rubber plantation enterprises Depend largely on high rate of fertilizer supplementation because Rubber is a high nutrient demanding crop especially During the immaturity phase of their growth and Development (1 – 4 latest 6 years).

Optimum rubber growth and High quality latex output therefore depend largely on the Ability of the farmer to determine controlling factors and Properly adjust them to suit rubber production. A major Factor in any plant growth is the soil which determines the Availability of nutrients required by the plants.

A proper Understanding of the physical and chemical properties of the soil is necessary to make proper amendmets early enough that would ensure good return on investment at later productive stages of rubber.

The cost of the project (plantation) is very cheap and avoidable as the planting facilitate inter-cropping (planting of other crop in the same land) by manipulating the gap between the rubber tree for some years for other profitable crops, such as maize early and late plantation (May-July and August-October) this will later be discuss in this manual.

This manual therefore, provides through several research practical Measures necessary for sustainable and economically viable rubber cultivation in the western region of Nigeria covering Oyo State Especially Ibadan, Ogbomosho, Saki, Oyo Town etc., Osun State especially Ialupon, Ikere, Ife, Ilesha, Erin Ile, Ijebu Jeshu, and other places, also Ogun State especially water side, Ijebu Igbo, Ijebu, etc, Ondo State, Ore, Okitipupa, Akure, Ondo Town, Odigbo, Ilaje, Ikare, Akoko, Owo etc.

Chapter 1

Rubber Seedling Nursery

Seedling nurseries are established for the production of budded stumps, stumped buddings and budwood
Budwood: an outgrowth on a stem or branch of a rubber tree consisting of a shortened stem

- **Selection of Site**

The site selected for a ground nursery should have good accessibility for supervision and transport of materials. If the purpose of the nursery is to raise materials for planting a large area in the estate, it may be located at a suitable site within this area itself. A good soil depth of at least 75 cm is essential. Loamy soils are ideal for ground nurseries. Extremely sandy soils are not suitable since leaching of plant nutrients is faster. Retention of moisture is poor in such soils, necessitating frequent watering during summer months. Soil containing too much of clay are also unsuitable mainly because of poor drainage. A well-drained level area is ideal for a nursery since the various operations will be easy and cheap in such sites. However, undulating lands are also suitable if adequate soil conservation measures are adopted. Contour terracing is done where the slope is in excess of two per cent. Waterlogged areas should be avoided and water table should be sufficiently low to allow sufficient soil depth for root development. Shade free areas are preferred. Land with a history of intensive cropping needs proper build up of the nutrient status to the satisfactory level.

- **Preparation of Nursery Beds**

For the preparation of a ground nursery, the soil is first dug to a depth of 60 to 75 cm. Stones, stumps, roots, etc present in the soil are removed and the soil is brought to a fine tilth. Beds should be 90 to 120 cm wide and of convenient length. In the level lands, raised beds are made with footpaths of about 45 cm width between the beds, and in undulating lands, beds are prepared along the contours, one below the other. At the time of preparation of nursery beds, 25 kg of compost or well-rotten cattle manure and 4 kg of powdered rock phosphate (18% P_2O_5) are incorporated for every 100 m² of nursery bed. When nurseries are established in newly cleared forest areas rich in organic matter, compost or cattle manure need not be applied during the first year. Similarly when the same area is repeatedly used as a nursery, rock phosphate need be applied only once in three years. Drainage and pathways should be provided appropriately.

- **Seed Germination Beds**

Rubber seeds are first germinated in germination beds and then planted in nursery. A well-drained area with moderate shade is the ideal site for germination beds. Level beds of 90 cm width and convenient length are prepared with walking space in between. The beds should be raised 10 to 15 cm above the soil surface to avoid waterlogging. A free draining friable material, like river sand, spread above the bed to a thickness of 5 cm is used as the medium for germination. Rubber seeds are viable only for a short period and are put in germination beds as soon as obtained. Seeds are washed thoroughly to remove charcoal and other packing debris and spread over the bed in a single layer touching one another and pressed gently into the sand. In order to prevent loss of too much moisture from the rooting medium, the beds are covered with a thin layer of gunny bag, coir matting or similar material. A high level of moisture is maintained in the bed by evenly sprinkling water early in the mornings and late in the evenings. Germination of the seeds starts within six to seven days after sowing. The beds should be inspected daily and the germinated seeds picked up and collected in a bucket containing water as soon as the radicle emerges for planting in the nursery beds or main field. If the picking of germinated seeds is delayed, chances of damage during handling will be

greater. Seeds which do not germinate within two to three weeks should be discarded as they are likely to give rise to weak seedlings.

- **Soil Type**

Soil in the rubber tract is generally highly weathered and consists mostly of laterite, lateritic types. Sedimentary types and nonlateritic red and alluvial soils are also seen in some non-traditional areas. The laterite and lateritic soils are mostly very porous, well drained, moderately to highly acidic, deficient in available phosphorus and varying in potassium and magnesium content. Red soil found in some areas is characterized by reddish to brown colour and fine loamy texture. This soil is generally acidic and highly deficient in available phosphorus.

- **Soil Depth**

Soil for rubber cultivation should have a minimum depth of one metre without any intervening hardpan or impenetrable layer. Water table should also be well below one metre so that at least one metre of soil with good aeration, essential for root penetration is available.

Chapter 2

Nursery Establishment

Nurseries are established and maintained for raising various propagation materials for planting. These include seedling stumps, budded stumps and advanced planting materials like polybag plants, stumped buddings and soil core plants. Mother plants or source bushes for the multiplication of budwood are also grown in nurseries. Raising of plants is easier and cheaper in nurseries than in the main field. Moreover, nurseries offer an opportunity for selection of vigorous and uniform plants.

- **Planting in Nursery**

For planting germinated seeds in the nursery beds, small holes enough to accommodate the seeds in a horizontal position and approximately 5 cm deep are made. The seeds are carefully placed in the holes with the radicle pointing downwards and covered with soil. The sprouted seeds should be planted when the young root is less than 2 cm long. The germinated seeds should be carefully handled to prevent damage of the radicle. Spacing varies according to the type of planting material to be raised in the nursery. The common spacing adopted for raising seedling stumps is 30 x 30 cm. To produce green-budded stumps 23 x 23 cm spacing may be followed. For brown-budded stumps a spacing of 30 x 30 cm or staggered pairs of rows 60 cm apart and 23 cm between plants may be adopted. A spacing of 60 x 60 cm, 90 x 30 cm, 90 x 60 cm or 90 x 90 cm is required to produce various kinds of stumped buddings. For raising soil core plants, a spacing of 35 x 35 cm, 38 x 30 cm or 60 x 60 cm may be followed. The spacing adopted for budwood nursery is 90 x 60 cm or 120 x 60 cm., wider spacing being between rows.

The rows are first marked on either end of each nursery bed using row markers. A long cord of coir rope, wire or country twine, with the planting distance along the row marked on it, is stretched tight along the length of the bed on the row markers on either end and germinated seeds are planted at each mark along the line. In budwood nursery, budded stumps are planted at the required spacing. Alternatively, seeds can be directly sown

in the beds at the required spacing and budded in situ. After budtake they are cut back and the scion allowed to develop.

Chapter 3

Types of Seedling Nursery

- **Budwood Nursery**

Buds required for budgrafting are collected from budwood obtained from plants raised specifically for this purpose. Budwood nurseries are of two types, namely brown budwood nursery and green budwood nursery. The former produces brown buds while the latter, green buds.

Site selected for establishing the budwood nursery is first cleaned and levelled. Terracing is done on slopes. Soil is first dug to a depth of 45 to 60 cm. Planting can be done with polybag plants, budded stumps or seed at stake followed by budding. Spacing usually adopted for brown budwood nursery is 90 x 60 cm. For green bud shoot nursery the spacing is 1 x 1 m or 80 x 90 cm. Proper fertilizer application may be carried out to ensure good growth. Other agronomic practices such as irrigation, mulching, weeding, shading, protection against diseases and pests are followed in a similar manner as for seedling nursery. Details on this can be found at Sections "Manuring/Fertiliser Application", Weed Management", Mulching, Shading and Whitewashing" etc. During the first year of planting only one shoot is allowed to grow. About 1 m of brown buddwood can be obtained from this after one year. From the second year, two or three shoots are allowed to develop on a plant depending on the spacing adopted. To remove the leaves present in the brown-coloured budwood, the leaflets are first removed by clipping the tip of the leaf stalk. After about one week the leaf stalk dries and falls off. Budwood is then harvested by sawing off, leaving about 15 cm at the base. From this portion shoots develop in the subsequent season. Green bud shoot plants are shaped from brown budwood plants. For this, a well-established brown budwood plant is first cut back at a height of about 75 cm. A number of shoots emerge below the cut end. Among these, three to five most vigorous ones alone are retained and the rest removed. When these shoots have grown and produced brown wood to a length of about 5 cm they are pruned at the point where the brown colour ends so as to produce more branches. Two to three most vigorous branches are retained on each shoot and the others cut off. When these secondary branches develop brown colour at the basal 5 cm they are again pruned. New branches arise from these and give the budwood plant a bushy appearance. For producing green shoots, all the branches of a green bud shoot plant (also called source bush) are pruned. The new branches arising are harvested when one whorl of leaves develop. The harvested budwood is cut into pieces of convenient length before being taken to the nursery beds for budding.

- **Polybag Nursery**

Planting materials in polybags can be prepared by two different methods. Budded stumps can be planted in polybag and the scion allowed developing till they are ready for planting in the field. In the other method, germinated seeds are planted in polybags and bud-grafted when five to six months old. The former gives greater opportunity for selection of the most vigorous plants and avoids wastage of bags containing poor seedlings and budding failures. The roots of budded stumps can be treated with indolebutyric acid (IBA), a hormone which enhances root growth. Dipping root in cow dung slurry before planting enhances root

development. The bags may be of black or transparent polyethylene. Transparent bags, when used, should always be kept buried in soil, as otherwise, the development of roots will be affected. The use of black polyethylene bags is generally preferred. Depending on the size of the plant to be produced, bags of different dimensions may be used. Polythene bags of lay flat dimension 55 to 60 cm length and 25 to 30 cm width which can hold about 8 to 10 kg soil are usually used for raising plants up to two to three whorlstage. For producing plants of six to seven whorls, larger bags of 65 x 35 cm size and holding about 23 kg soil should be used. In order to facilitate drainage, sufficient number of holes should be punched on the lower half of the bags. Low density polyethylene (LDPE) sheet of 400 gauge and 500 gauge thickness are usually used for making small bags and large bags respectively. Bags made of high density polyethylene (HDPE) sheets can also be used for this purpose. However, such bags are likely to deteriorate when exposed to sunlight for long periods. The soil used for filling the bags should have good moisture and nutrient retention capacity, promote root development and bind the roots firmly to prevent damage during transport. Soils with clay-loam texture, good structure and friability are ideal for this purpose. The fertile topsoil collected after removing the surface vegetation and leaf litter is ideal for filling the bags. Before filling, large clods of soil are broken, and if too wet partially dried. The soil is cleaned by removing stones, roots and stubbles. While filling, the bag should be gently tapped to ensure compact filling of soil without leaving air spaces. The bag is filled up to about 2 cm below the brim. Powdered rock phosphate at the rate of 25 g for small bags and 75 g for large bags is mixed with the top layer of soil. The filled bags can be kept in the nursery either in trenches or on the ground supported with wooden poles. The former method is better as it would give greater protection of the bags and better growth of the plants. Trenches having width equal to the diameter of the bag are usually dug in pairs. For small bags, depth of trench may be about 20 cm and the distance between rows in a pair of trenches 15 cm. The corresponding depth and distance for large bags are 30 cm and 20 cm. The gap between bags of same trench is 10 cm. Footpath of 75 cm width may be left between two pairs of trenches. After placing the bag in the trench, the excavated soil is filled in the gap between them. The remaining soil is mounted around the bags. Planting of budded stumps or sprouted seeds is undertaken thereafter. When budded stumps are used, the bud patch should face the footpaths to facilitate growth of sprouts. Regular cultural operations like manuring, watering, weeding, shading and plant protection are adopted. Application of NPK Mg 10-10-4-1.5 mixture is done at monthly intervals. During the first month 10 g of the mixture is given per bag which is gradually increased to 30 g in four months' time. Fertilizer application should be avoided when the leaves are very tender. While applying fertilizer, care should be taken to prevent it from coming in contact with the young plant as it may cause scorching. Watering should be done soon after manuring. During dry periods, irrigation should be done regularly. Watering can be done manually in small nurseries while sprinklers or drip irrigation system is more economical in large nurseries. Too much watering should be avoided to prevent waterlogging. During summer months, partial shade may be provided to the plants by erecting overhead shade. Appropriate prophylactic and curative measures may be taken against diseases and pests. Polybag plants are advanced planting materials which contribute to reduction in immaturity period. Bagged plants should be transplanted to the field, with minimum disturbance to the root system for proper establishment. Such plants also help to achieve a uniform stand and are also useful for vacancy filling and late planting. Because of these advantages the use of polybag plants has become very popular.

Chapter 4

Land Preparation

Rubber plantations are established in forest clearings, rubber replanting or by crop replacement. Most of the areas available for rubber cultivation are highly undulating and the extent of flat lands suitable for planting rubber is limited. These situations necessitate clearing of the land and adoption of proper soil conservation

measures before planting rubber.

Since June-September is the ideal period for planting rubber in Nigeria, all the pre-planting operations should be completed before the onset of monsoon. Following the siting and scaling of the land digging is what follows while planting of the seed/storm immediately follows for a normal plantation in practice.

Chapter 5

Clearing

The land to be brought under rubber cultivation should be cleared of all vegetation. Large trees of economic value should be removed first followed by felling and removing of smaller trees and slashing of the under growth. A light burn after felling and drying facilitates planting operations and slows down the regeneration of weeds. Nevertheless, excessive cleaning and burning may cause the destruction of soil and expose the soil to erosion. Replanting the old areas has to be thought of when the yield falls and the cultivation becomes uneconomic. The old trees may be slaughter tapped with yield stimulant application before felling. Lining and digging of pits can be started before felling of trees to save time. But there are chances of damaging the terraces at the time of felling. In addition, there will be a need to separate fire-barrier from the land while clearing this fire barrier is to be cleared without giving way for any weed to fall therein, this is to protect the rubber farm in case there comes fire outbreak from other/your farm it will not affect the other farm/your farm it will also protects your farm from getting affected from infected farm around. We all the project I have succeeded in planting I never joke about fire-barrier no matter how small the land is.

Chapter 6

Roads, Fences and Buildings

A well-planned network of roads and footpath is necessary for the easy transportation of inputs to the various fields, latex to the factory and for the efficient supervision of field operations. The roads should be preferably traced before the commencement of lining so that sufficient strip of land could be reserved. Sufficient provision should be made for estate office, stores, processing factories and residential accommodations. The plantation should be protected all around by erecting fences or walls to keep away grazing cattle and to prevent pilferage.

For a proper scaling the land future use of the land should be made know in other to have a proper rubber farm this is so because if there should be a case of the constructing road close to the land in the later time it will affect some of the rubber, so it is important to measure some part of the land for road land-scalping before the fire-barrier. In a rubber project at Olorundaba, in Ibadan a road is said to be constructed near the land and for that reason we have to leave about 6m (according to Oyo State standard) before the fire-barrier.

• Lining

Lining should be based on plant spacing and planting density to be adopted. Rubber can be planted by adopting square or rectangular planting system. Square planting is suitable for level and near level lands. Rectangular system can be adopted in flat lands and slopes. In rectangular planting the lines should be oriented in the East West direction to intercept maximum sunlight. Contour lining is done in undulating and hilly areas where the slope exceeds 8 per cent. Here the planting points are marked as lines passing through points of the same elevation. The planting density recommended is 420 to 500 plants per ha in the case of buddings or plants proposed to be field budded and 445 to 520 plants per ha in the case of seedlings. Higher initial stand is

recommended for allowing proper thinning out.

Density of Plants under Different Terrains and Planting Materials			
Planting material and terrain		Spacing (metre)	Stand/ha
Buddings:	in hilly areas	6.7 x 3.4	445
	in flat area:		
	Square	4.9 x 4.9	420
	Triangular	4.9 x 4.9	470
Seedlings:	in hilly areas	6.1 x 3.0	539
	in flat area: square	4.6 x 4.6	479

- **Terracing**

On hilly and undulating terrain, cutting of terraces along the contour is a recommended practice to conserve moisture and prevent erosion.

The soil on the hill side is cut from a distance of 60-75 cm in front of the planting row and thrown back in such a way that the terraces so formed will have a width of 1.25 to 1.5 metre and an inward drop of 20-30 cm. Steps of uncut earth are left out at intervals along the terraces to check lateral flow of water. For economy, planting on hillside may be done on square platform of size 1.25 x 1.25 metre (honey comb terrace) during the year of planting and later on joined together to form a complete terrace.

Chapter 7

Manure/Fertilizer Application for seedling nursery

Basal Dressing – Incorporate two and a half tones of compost or well-rotted cattle manure and 400 kg of powdered rock phosphate (18% P_2O_5) for every effective ha, i.e., 25 kg of compost and 4 kg of rock phosphate per 100 m² of the nursery bed. If the nursery is opened in a newly cleared forest area, addition of compost or cattle manure may not be necessary during the year of opening and application of rock phosphate alone is sufficient. If the same bed is used repeatedly, application of rock phosphate is necessary only once in three years.

Top Dressing - Apply 2500 kg of 10-10-4-1.5 NPKMg mixture per effective ha, i.e., 25 kg per 100 m² of the nursery bed six to eight weeks after planting. Again apply 550 kg of urea per effective ha, i.e., 5.5 kg per 100 m², six to eight weeks after the first top dressing. After fertilizers application the plant bases can be mulched with suitable mulch material.

The first application of the recommended quantity of NPKMg mixture should be made during September-October period, i.e., six to eight weeks after planting the germinated seeds in the nursery beds. The fertilizer should be spread about eight cm away from the base of the plants in a 14 cm wide linear band in between two rows and gently forked in with a hand rake. The fertilizer should not come into contact with the stem of the

seedling to avoid injury to the plants and ensure that there is sufficient moisture in the soil at the time of application.

Alternatively, you can use poultry waste after it has pass through the process of burning and parked in a big sake bag or bagco bag or cement bag for some days, up to 14-21days.

Chapter 8

Manure/Fertilizer Application for Budwood Nursery

The aim of manuring budwood nurseries is to obtain the maximum quantity of good quality budwood per plant at the intervals of 10-12 months with an initial period of 12 to 18 months for the first crop of budwood.

1. Incorporate 165 kg of powdered rock phosphate per ha i.e., 1.65 kg per 100 sq. metres of the nursery bed as a basal dressing at the time of preparing the nursery bed.
2. For the first crop of bud-wood apply 250 g of 10-10-4-1.5 NPKMg mixture per plant in two equal split doses. Apply the first split of 125 g per plant two to three months after planting the budded stump or cutting back if budding is carried out in situ. The second dose of 125 g per plant should be applied eight to nine months after planting.
3. For the second and subsequent crops of bud-wood from the nursery, apply 125 g of 10-10-4-1.5 NPKMg mixture per plant in one single dose two to three months after cutting back.

The fertilizer application should be made during September – October and March-April either in a band 8 cm away from the base of the plant or in between two rows and lightly forked with a hand rake. For the second and subsequent crops of bud-wood the one round of fertilizer application recommended should be applied during September-October season adopting the same method.

Alternatively, you can use poultry waste after it has pass through the process of burning and parked in a big sake bag or bagco bag or cement bag for some days, up to 14-21days

Chapter 9

Field Planting

The success of planting depends on the prevailing weather conditions, quality of the planting materials used and the care with which the planting operation is done. Continuous wet weather can be expected during June-July in the major rubber growing areas in India and hence this period is considered to be ideal for planting rubber. The actual method of planting will depend on the materials used for planting. Different types of planting materials used are seeds, seedling stumps, budded stumps and polybag plants. Of these, the last two are the most common ones.

• Seed at Stake Planting

The system of planting seeds in some countries is called seed at stake planting and it is followed by field budding. Two or three germinated seeds may be planted in a line or triangle. The weaker plants should be thinned out later, allowing the most vigorous one to grow on which field budding is carried out at the appropriate stage.

• Seedling Stumps and Budded Stumps

It is always advisable to plant the stumps soon after pulling out from nursery beds. While planting budded stumps, the bud patch should be just above the ground level. If a considerable part of the stock below the union is left above the ground level, it may maximize the effect of 'elephant foot.' If kept below the soil the union is likely to be infected by soil organisms.

About 5 cm of surface soil is first removed from an adequate area around the planting points to accommodate the whorl of lateral roots. The side roots are set neither too shallow nor too deep. Special attention should also be given to ensure that the tip of the taproot is in actual contact with the soil at the bottom of the cavity. Air gap should not be allowed in the planting cavity as it may lead to failure of root development. Loose soil is put in the cavity around the taproot and pressed firmly. This process is repeated on all sides without causing any damage to the bud. Loose soil on the surface of the refilled pits should be stamped and pressed down firmly. The level of soil around the planted stump should be a centimeter or two above the ground level so that rainwater does not collect around it. Stumped buddings are also planted in the same manner.

Chapter 10

Polybag Planting

At the time of planting, the top whorl of leaves of the polybag plant should be fully mature. The soil around the bag is removed and the bags are taken out of the trench. Dressing of the lateral roots and taproot, if grown out of the bags, may be necessary. Then they are carried to the planting points. A planting hole slightly bigger than the size of the bag is made. The bottom of the bag is completely cut and then the bag along with the plant is inserted into the planting hole. A vertical cut is made at the bottom of the plastic sleeve, taking care not to damage the roots. Then the cut is continued upwards as the hole is gradually filled so that the cylinder of soil is unbroken. When the hole is partially filled, the bag is slit along its full length and carefully pulled away. The soil is finally packed firmly around the plants. While planting, the scion of the polybag plants should be directed towards north east to minimize the adverse effect of direct sunlight on the bud patch.

Chapter 11

Aftercare

After planting, the plants should be inspected at regular intervals and the false shoots sprouting from the stock should be removed and only the vigorous bud shoot is allowed to develop. Any side shoot developing up to 2.5 metres from the ground level should also be removed. This is important to give room for fast growing of the tree, it should be noted that when removing the false sprouting from the stock/tree you must not allow the object used to creep the tree body.

Chapter 12

Mulching, Shading and Whitewashing

Mulching or covering the plant basin with dry leaves, cover crop cuttings, grass cuttings, paddy straw etc. is a recommended practice in rubber plantations to protect soil in the immediate vicinity of the plants from direct impact of heavy rains and sunlight causing soil degradation. Dried African Payal (*Salvinia* sp.) also can be effectively used as mulch at the rate of 5 kg per square metre (sun dried material).

- **Benefits of Mulching**

- * Improvement of water and plant nutrient holding capacity of the soil

- * Maintenance of the soil around young rubber plants in a cool and moist condition during summer months
- * Multiplication of microbial population of the soil, ensuring better nutrient availability
- * Protection of the soil from beating effect of heavy rainfall resulting in soil erosion
- * Control of weeds around the plant bases. Mulching should be undertaken in nurseries and young plantations after fertilizer application and before the onset of regular summer. Usually, November is the ideal time for mulching to protect the plant from adverse effect of drought. During the year of planting young plants may be protected by shading before the beginning of summer. Plaited coconut leaves or used gunny bags can be used for this purpose. The brown bark of the young plants can be protected from the scorching action of the sun by whitewashing the main stem of the plant from the second year of planting. This may be continued till canopy of the plants develops and partially shades the plantation. However, plants on the roadsides may need whitewashing for a longer period as they are more exposed to sunlight. Whitewashing can be done using lime or china clay.

• **Protection of Young Rubber Plants from Strong Sun**

Young rubber plants in the field and nurseries are highly susceptible to scorching resulting from exposure to strong sun. The incidence is more on southern and southwestern aspects. Mulching and shading help prevent sun scorch in nurseries. In the field too, mulching and provision of bamboo or plaited coconut leaf tree guards afford same protection in this regard. From the second year onwards, young plants in the field may be protected by whitewashing brown portions of the main stem. This is done by the beginning of the dry weather, that is during November – December. For white washing, fresh lime is superior even though china clay can also be used.

Chapter 13

Induction of Branches

It has been observed that to achieve a high rate of girth increase the rubber plant should produce branches at a height of about 2.5 to 3.0 m from the ground. In high branching trees girth increment has been found to be poor compared to low branching trees. Some plants show a tendency for high branching, particularly clones like RRIM 600 and GT 1. In such cases branching has to be induced by encouraging a few lateral buds to develop. The branches thus induced should develop in different directions in an equally spaced manner to ensure a well-balanced canopy. Techniques like the double blade ring cut device and the leaf cap method can be utilized for this. The double-blade ring-cut device has two V-shaped blades fixed 20 cm apart on a rod. By pressing the V-shaped blades and rotating them around the trunk complete ringing of the bark is done down to the surface of the wood. The cuts are made above a cluster of leaf scars so that a number of trunk shoots is produced around this region. This method can be applied only on greenish brown or brown tissues and is not suitable for young green tissues. In young green tissues, the leaf folding or leaf cap method can be used. In the leaf folding method, the leaves of the top whorl are folded down at the point of contact of the petiole with the lamina using only the upper few leaves to enclose the apical bud. The leaves are then tied with a rubber band. After three to four weeks they are released. In plants where the terminal whorl of leaves is in the leaflet or bud break stage, the leaf cap method is recommended. Here, three mature leaflets are taken to form a cap to enclose the terminal bud and tied with a rubber band. The cap is then removed three to four weeks later.

Chapter 14

General Manure/Fertilizer Application

- **General Fertilizer Recommendation**

The general fertilizer recommendation for rubber is derived based on the results of the fertilizer experiments conducted by the Rubber Research Institute of India on rubber of different age groups. Majority of the rubber growing soils belong to the laterite and lateritic types and hence this general fertilizer recommendation can be followed. However, practicing discriminatory fertilizer recommendation based on soil and leaf analysis will be more advantageous.

The nutrient requirements of rubber plant vary considerably during the three important stages of growth; the nursery, immature and mature stages.

- **Mature Rubber under Tapping**

- The general recommendation is 30-30-30 NPK kg/ha. This can be supplied through mixing straight fertilizers or through mixtures. The quantity of the same is provided in an earlier session (manuring from 5th year till attainment of maturity for well-maintained plantations). Discriminatory fertilizer application based on the results of soil and leaf analysis should be practiced for mature rubber wherever it is possible.

- **Method of Application**

Fertilisers should be applied in square or rectangular patches in between rows, each patch serving four trees. Once the canopy of the plants closes, say, 5 to 6 years after planting, light forking to incorporate the fertilisers into the top soil is necessary. In areas where the legume ground cover is present or where the legume cover has died out leaving a thick mulch, it is enough to broadcast the fertilisers between two rows of rubber trees. Deep pocket placement of fertilisers and application too close to the base of the trees should be avoided.

- **Immature Rubber**

- **Up to the fourth year**

the object of manuring rubber plants during the immature stage is to accelerate the growth and to reduce the unproductive phase of the crop. Under the agro-climatic conditions prevailing in the traditional tract, rubber plants after planting takes about seven years to attain tappability in most cases. The result of the field experiments carried out by the Rubber Research Institute of India clearly indicated the possibility of reducing the immaturity period by one year through systematic manuring and agro management practices in the young rubber plant.

1. Pit manuring: Incorporate 12 kg of compost or well-rotted cattle manure and 200 g of rock phosphate in every pit at the time of filling to provide good soil conditions for development of a good root system. In newly cleared forest areas it is enough to apply 200 g rock phosphate alone, well mixed with the top 20 cm soil in the pit as the surface soil in general will be rich in organic matter.
2. The quantity and schedule of manuring for the first four years are shown below. The quantity requirement for 10-10-4-1.5 NPKMg mixture or 12-12-6 mixture is provided. The required dose of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) can be provided through mixing the straight fertilisers. The quantities of straight fertilisers needed for preparing these fertiliser mixtures are also shown. Two grades of mixtures, one with Mg and the other without Mg is provided for application in Mg deficient and Mg rich areas respectively. In Kanyakumari district of Tamilnadu, Thrissur, Palakkad, Malappuram, Kozhikode, Waynad, Kannur and Kasargod districts of Kerala, in the states of Karnataka, Goa, Maharashtra and N. E. India, the available Mg status of the soil is high and application of 12-12-6 NPK mixture is recommended. In all other regions 10-10-4-1.5 NPKMg mixture may be applied.

Quantity and the Schedule of Fertiliser Application during the First Four Years

Year of planting	Month after planting	Time of application	Dose of mixture per plant (g)		Quantity of mixture per ha with 440-450 plant points (kg)	
			10-10-4-1.5	12-12-6	10-10-4-1.5	12-12-6
			(NPKMg)	(NPK)	(NPKMg)	(NPK)
1 st year	3 months	Sep - Oct	225	190	100	85
2 nd year	9 „	Apr - May	450	380	200	170
do	15 „	Sept - Oct	450	380	200	170
3 rd year	21 „	Apr - May	550	480	250	215
do	27 „	Sept - Oct	550	480	250	215
4 th year	33 „	Apr - May	450	380	200	170
do	39 „	Sep - Oct	450	380	200	170

1. In the case of poly bag plants, during the first year, i.e. three months after planting (Sept-October) apply 450/380 g of the fertiliser mixture instead of 225/190 g shown in the Table.
2. If no leguminous ground covers were established in the field, the fertiliser recommendation for the third year may be continued during the fourth year also.

In the first two years it is advantageous to apply 50 per cent of the phosphorus in the water-soluble form for better growth of the rubber plants. Therefore during the first two years, 10-10(5)-4-1.5 NPK Mg mixture and 12-12(6)-6 NPK mixture containing 50 per cent of the phosphate in the soluble form are recommended.

Composition of Different Fertiliser Mixtures

Mixture	Quantity of straight fertilisers (kg)					
	Urea	AP	RP	MOP	Mg	Filler
15-10-6 NPK	33.0	-	55.0	10.0	-	2.0
10-10-10 NPK	22.0	-	55.0	17.0	-	6.0
10-10-4-1.5 NPKMg	22.0	-	55.0	7.0	4.0	12.0
10-10(5)*-4-1.5 NPKMg	11.0	25.0	28.0	7.0	4.0	25.0
12-12-6 NPK	26.0	-	64.0	10.0	-	-
12-12(6)*-6 NPK	13.0	30.0	33.0	10.0	-	14.0

- 50% water soluble P through AP

AP – Ammonium Phosphate (20-20 NP)

MOP – Muriate of Potash (60% K₂O)

RP – Rock Phosphate (18% P₂O₅)

Mg - Magnesium Sulphate (16% MgO)

The fertiliser requirements of rubber during the remaining period of immaturity depend to a great extent on the cultivation practices, such as mulching the plant bases during the initial years and the establishment and maintenance of leguminous ground covers in the field. These cultivation practices will result in the improvement of the soil conditions and availability of plant nutrients, particularly nitrogen.

Method of Application

For young rubber, fertilisers should be applied taking into consideration the extent of root spread. During the first application after planting, fertilisers should be evenly distributed over a circular band of about 30 cm around the base of the young plant, leaving about seven cm from the base all around and slightly forked into the top five to eight cm of the soil. The plant bases should then be immediately mulched. This will help in better retention and utilization of the applied fertilisers and control of weed growth in the plant bases. The second round of fertiliser application, i.e., when the plants are 9 months old should be done in a circular band, the band width being 45 cm leaving 15cm all around the plant base. The fertiliser applications in subsequent years till the canopy of the rubber plant closes should be made in circular bands of steadily increasing width.

- **From the fifth year of Planting to Maturity**

A. The fertiliser recommendation from the 5th year of planting for a well maintained field where mulching was practiced and leguminous ground cover was established and maintained is 30,30,30 NPK kg/ha. By mixing the straight fertilisers, 65 kg of urea, 165 kg rock phosphate and 50 kg of muriate of potash, this can be supplied. Otherwise 300 kg/ha of 10-10-10 NPK mixture can be used. Alternatively, any of the complex fertilisers of the grades 15-15-15 or 17-17-17 or 19-19-19 NPK may be used and the quantities of these should be 200,175 or 160 kg/ha respectively. 10-26-26 NPK complex (115 kg) mixed with urea (40kg) or Ammonium phosphate sulphate (Ammophos), 20-20 (150kg) with muriate of potash (50kg) or 65 kg Diammonium phosphate (DAP) mixed with 40kg urea and 50 kg muriate of potash may also be used. Diammonium phosphate is recommended for soils having pH 6.0 or above which is very rare. B. For areas where no legume ground covers were established and no mulching practiced during the initial years, the recommendation is 60,40,24 NPK kg/ha by mixing straight fertilizers - 130 Kg urea, 220 Kg Rajphos and 40 Kg MOP. The quality has to be applied in two equal splits in two seasons. This can also be supplied through 400 kg of 15-10-6 mixture applied in two split doses of 200 kg each during the 5th and subsequent years till the plants become ready for tapping.

Chapter 15

Intercropping

During the initial years of a rubber plantation, the land area is not fully occupied by the rubber plants and inter spaces are available in the plantation which receive plenty of sunlight. These interspaces can be utilized for growing intercrops, which will help the farmer to generate additional revenue. Intercrops should be planted atleast 1.5 M away from plant bases. Intercrops should be separately and adequately manured.

The topography of the rubber plantations vary from level lands to gentle, moderate and steep slopes. The high rainfall in the rubber growing regions and the undulating topography in many situations make the soil vulnerable to erosion hazards. Growing of inter crops necessitates soil disturbing tillage operations of various kinds. This will predispose the top soil to erosion losses in steep and undulating lands. The growing of intercrops, therefore has to be restricted to level lands and gentle slopes. Even in such lands it should be ensured that leguminous cover crops are established side by side with intercrops or immediately after the intercropping is stopped. The general practice of growing leguminous ground covers has to be strictly followed in plantations of moderate and steep slopes.

The Common Intercrops Cultivated in Rubber Plantations

Banana, maize, Vegetables, Tuber crops, others: coconut, pineapple, moringa, etc.

- **Banana**

Banana is suitable as intercrop during the initial three years. During the first year 1200 plants per hectare can be grown in a double row system at 2 x 2 metre spacing. The stand should be restricted to 600 during the second year in a single row system and 450 during third year. Ratoon types like 'Palayankodan', 'Poovan' etc. should be planted in a single row and only one sucker should be retained during the second year. The pseudo stem, leaves and mother rhizome left after harvest can be used for mulching the rubber plant.

- **Maize**

Many people ask questions about maize plantation well this is another opportunity for you to know how to plant maize the reason I take maize separately here is because maize is what most of most of the farmer here love most to plant as it season is well monitored by the farmer, well the early maize is planted may and the late is planted august, so it is advisable to plant maize for the inter-cropping period.

- **Vegetables**

Many vegetables like cowpea, cucumber, ladies finger, amaranthus etc. can be grown during the initial 2-3 years with proper addition of organic manures.

- **Tuber crops**

Amorphophallus, dioscorea, calocasia and arrowroot can be cultivated as inter crop during the initial years of plantations. These crops can be grown alone, in mixed pattern along with banana or sequentially after one or two crops of banana or vegetable and can be retained upto 4 - 5 years. Since cultivation of these crops need filling the soil to varying degrees their cultivation should be restricted to level lands and gentle slopes and tillage operations should be kept to a minimum. When dioscorea is cultivated, along with rubber, the vines should be trailed on artificial supports.

Chapter 16

Diseases and Pests

Crops losses resulting from ravages of disease causing agencies in rubber plantations are substantial. Timely plant protection operations ensure healthy growth and economic production. The major diseases and pests of rubber are given below.

- **Types Of Diseases And Pests**

Abnormal Leaf Fall, Shoot Rot, Powdery Mildew, Colletotrichum Leaf Disease

Bird's Eye Spot, Leaf Spot, Pink Disease, Patch Canker or Bark Canker, Black Stripe, Black Thread or Black Rot, Dry Rot, Stump Rot Collar Rot or Charcoal Rot, Brown Root Disease, Poria Root Disease, Scale Insect, Mealy Bug, Termite (White Ant), Cockchafer Grub, Bark Feeding Caterpillar, Mites, Slug and Snail, Rat, Porcupines and Wild Pigs, Cover Crop Pests, Parasitic and Non-Parasitic Maladies, Sprayers and Dusters, Abnormal Leaf Fall

Crops losses resulting from ravages of disease causing agencies in rubber plantations are substantial. Timely plant protection operations ensure healthy growth and economic production. The major diseases and pests of rubber are given below.

Causative Agent: *Phytophthora palmivora* (Butl.) Butl and *P. meadii* Mc Rae

Occurrence: Noticed during south west monsoon period. Common during heavy rainfall periods.

Symptoms: The tender green shoots rot. More damaging for nursery seedlings and the young plants in the field.

Clonal Susceptibility: Clones, which are susceptible to abnormal leaf fall disease, are severely affected by this disease.

Control Measures: Prophylactic spraying as above for mature plants. For young plants in the nursery as well as in the field, spraying with copper fungicides before the onset of south west monsoon coupled with repeated spray rounds during bright breaks protect the plants. Phosphorus acid 0.16% (Akomin and Phosjet 4 ml/L) and metalaxyl Mz 0.2% (Ridomil Mz 2.77 g/L) are also effective. For ensuring proper sticking of the spray on tender foliage sticker (Sandovit, Tenac, Teepol, Triton AE etc) may be added at the rate of 0.5 ml/litre of spray fluid.

Powdery Mildew: Causative Agent: *Oidium heveae* Steinm.

Occurrence: Predominantly noticed on newly formed tender flush during the refoilation period of January to March. The disease is severe in Kanyakumari, Idukki and Wynad district of South India and North Eastern States. Cloudy days with light rains and/or misty nights with dew formation during refoilation favour serious disease outbreaks.

Symptoms: Tender leaves with ashy coating curl, crinkle, and edges roll inwards and fall, leaving the petioles attached to the twigs like a broom-stick. After a few days, the petioles also fall. Die-back of twigs follows. On older leaves white patches later causing necrotic spots reduce photosynthetic efficiency. Infected flowers and tender fruits are shed, affecting seed production.

Control Measures: Dusting during the refoilation period commencing from bud break in about 10% of the trees, giving 3 to 5 rounds at weekly to fortnightly interval using 11 to 14 kg 325-mesh fine sulphur dust per round per hectare. Sulphur mixed with an inert material like Talc (70:30) is commonly used. Wettable sulphur (Carbendazim 2.5 g/l) is also effective in nurseries and for young plants as a spray. Bavistin 0.05% a.i. (Bavistin 1g in 1 litre water) spraying is more effective than sulphur for nurseries and young rubber. Alternate use of Bavistin and sulphur is recommended to avoid resistance problem. For efficiency, dusting may be carried out in the early morning hours when the leaves are moist and the atmosphere calm. Power dusters like Skoda Micro spray power 400 or Aspee Turblow tree duster could be used for sulphur dusting.

Colletotrichum Leaf Disease: Causative Agent: *Colletotrichum acutatum* C.*gloeosporioides* (Penz.)Sacc.

Occurrence: Observed during April to October. In North East India the disease is prevalent throughout the year except during winter.

Symptoms: Infects tender leaves, mostly at the leaf tip region. Spots are small, brown in colour and is surrounded by an yellow halo. Numerous spots coalesce and dry up leading to defoliation. The infected leaves often crinkle and become distorted before shedding.

Control Measures: Spraying with Bordeaux mixture 1%, copper oxychloride 0.125% (Fytan 2.5 g/l) mancozeb 0.2% (Dithane/ Indofil M 45 2.66 g/l) or carbendazim 0.05% (Bavistin 1 g/l) at 10 - 15 days intervals is effective.

Leaf Spot: Causative Agent: *Corynespora cassiicola* (Berk & Curt)

Occurrence: Earlier the disease was confined to nurseries only. From 1996 onwards severe incidence of the disease was observed in mature plantations in the Dakshin Kannada District of Karnataka State and in the adjoining districts of Kerala. In nurseries, disease incidence is noticed during November to May period. On mature trees, disease is observed during the refoliation period from February to May.

Symptoms: Large spots, with brown margins and pale centre are the common symptom. The centre may fall off forming shot holes. On mature trees light green leaves during refoliation are more susceptible. Several lesions coalesce to form large blighted area. Disease spreads along the veins leading to a brownish "railway track" or "fish bone" like appearance. Even a localised infection on midrib or base of a leaf causes leaf abscission. Defoliation leads to die-back of branches.

Control Measures: Repeated spraying with Bordeaux mixture 1% or Dithane (Indofil) M-45 0.2% or Bavistin 0.02% is recommended for nursery. Shading the nursery reduces the disease incidence. Maintain seedlings in vigorous condition through adequate balanced nutrition. High volume spraying with mancozeb 0.2% (Dithane/Indofil M-45 2.66 g/l) carbendazim 0.05% (Bavistin 1g/l) at 2-3 weeks interval during refoliation is effective in mature plantation. Micron spraying with oil dispersible copper oxychloride 56% (8kg) or oil dispersible mancozeb 70% (7 kg) dispersed in 40 l spray oil per ha is also effective.

Patch Canker or Bark Canker: Causative Agent: *Phytophthora palmivora*, *Phytophthora meadii*, *Pythium vexans*

Occurrence: Infection mostly during the wet weather.

Symptoms: On the tapping panel region, or anywhere on the stem including the collar region and occasionally on the roots. Swelling and bark burst with amber-coloured liquid oozing out. This may not be evident in all cases. In most cases oozing of latex is observed. The bark rots, and a coagulated rubber pad, emanating a foul smell is seen in between the wood and the rotting bark. When this is removed slight discolouration of the wood in this region is also noticed.

Control Measures: The affected region may be scraped to remove all the rotting bark and the coagulated rubber and the wound washed well with mancozeb 0.75% (Dithane/ Indofil M-45 10 g/l). When the fungicide dries up, apply wound dressing compound.

Scale Insect: Causative Agent: *Saissetia nigra* Nietn.

Occurrence: Seen generally in young plantations and nurseries in almost all rubber areas.

Symptoms: Small insects with an outer black, dome-shaped covering. Occur on leaflets petioles and tender shoot portions and suck the sap, severely affected portions dry up and die. Ants and sooty mould are associated with this.

Control Measures: Natural enemies like insect parasites and entomogenous fungi keep this pest in check. When severe infestation is noted, spray Organophosphorus insecticides like Malathion at 0.05% concentration.

Mealy Bug: Causative Agent: *Ferrisia virgata* Ckll

Occurrence: Seen mostly in nurseries in all rubber areas

Symptoms: Soft bodied small insects with white mealy outer covering. Occurrence and damage similar to scale insects.

Control Measures: Spray Organophosphorus insecticides like malathion 0.1% (2 ml/l) or quinalphos 0.075% (Ekalux 25EC3 ml/L)

Cockchafer Grub

Causative Agent: *Holotrichia Serrata* F. *H.rufoflava* Brenske, *Anomala varians* Ol.

Occurrence: More prevalent near forest areas and in loose soils.

Symptoms: Feeds on the roots of seedlings in the nursery and young plants. The affected plants droop and fall over.

Control Measures: Incorporate 25 kg per hectare of Phorate 10G in the soil at the time of bed preparation

Bark Feeding Caterpillar: Causative Agent: *Aetherastis circulata* Meyr. *Ptochoryctis rosaria* Meyr

Occurrence: Nagercoil, Nedumangad, Punalur, and Thrissur localities.

Symptoms: The caterpillars build galleries with faecal matter and silk all over the trunk region and branches of trees. Generally feed on dead bark and occasionally on live bark causing exudation of latex. Deep scar found at the regions of feeding.

Control Measures: When the infestation is severe apply Sevin 5% at the rate of 10 kg per hectare or Fenval 0.4% dust at the rate of 7 kg per hectare (provisional recommendation) with a power duster. Spraying the trunk with fenvalerate 0.02% (Tatafen 20 EC, Arfen 20 EC 1 ml/L) is also effective.

Mites

Causative Agent: *Hemitarsonemus dorsalis*

Occurrence: Sporadic incidence on young rubber plants in nurseries.

Symptoms: Not a serious pest. Minute organisms with four pairs of legs. Suck sap from the leaves resulting in crinkling and shedding.

Control Measures: Dust sulphur or spray sulphur 0.2% (Sulfex 80 WP 2.5g/L) or dicofol 0.05% (Kelthane 18 EC

Slug and Snail: Causative Agent: *Mariaellae dussumieri* Grey, *Crytozona (Xestina) bistralis* Beck

Occurrence: Distributed randomly in rubber areas in Kanjirappally, Thrissur and Calicut

Symptoms: Feed on latex by lacerating the tender leaves and buds. Growth of affected buds is arrested and side shoots develop giving a bunched appearance. Slugs drink latex from the tapping cut and collecting cup also.

Clonal Susceptibility: Nursery seedlings are more susceptible.

Control Measures: Broadcast 2.5% Metaldehyde bait pellets (snail kill 2.5) at the base of the infested plants or seedling beds. To repel slugs and snails brush Bordeaux Paste 10% around the stem above the bud union to a length of 30 cm. Repeat the application after 30-45 days if the attack continues.

Rat: Causative Agent: *Bandicota indica* Bech *Bandicota bengalensis* Gray, *Rattus melstada* Gray

Occurrence: Almost all rubber areas.

Symptoms: Feeds on kernels of seeds sown in germination bed. In young plants they gnaw the roots and the plants dry up.

Clonal Susceptibility: Nursery plants are more susceptible.

Control Measures: Distribute baits of poisons of Zinc phosphide with an attractive food like tapioca pieces or bait cakes of these poisons prepared with wax in different regions of the affected areas. Bromodiolone 0.005% a.i. bait is also found to be very effective. The single dose anticoagulant need be fed by the rats, only once.

Chapter 17

Tapping Panel Dryness

Generally high yielding clones of natural rubber are often considered susceptible to the physiological disorder commonly termed Tapping Panel Dryness (TPD) earlier referred to as Brown Bast. It usually occurs when the harvesting of latex from the trees exceeds the physiological capacity of its regeneration. It is estimated that TPD leads to approximately 15-20% decrease in yield. The common symptoms of TPD include an excessive late dripping of latex simultaneous with a drop in the dry rubber content of the latex in the initial phase and high DRC in the later stage. Total inhibition of rubber biosynthesis occurs and no latex is produced towards the final phase.

The most important symptom of TPD affected trees is partial or total drying of tapping panel which gives the name to the disorder. Besides cessation of latex flow, terminal symptoms like bulging, necrosis and cracking of the bark have been observed. Some clone specific TPD symptoms characterised by sloughing in PB 28/59 and scaling observed in clone RRIM 605 are also noticed. The symptoms are observed also on the root stock and root. In most of the partially affected trees, dry portion is confined only to the roots below the dry portion in the scion.

It is generally presumed that tapping panel dryness (TPD) is, by and large, a physiological disorder resulting from tapping induced abiotic stress to *Hevea* trees. In the light of recent reports, involvement of pathogens in some types of TPD seems to be a possibility, although results are far from being conclusive. Detection of pathogens using R-PAGE (Return Poly Acrylamide Gel Electrophoresis) has shown the association of LMW RNA similar to viroid in TPD affected trees and its role in causing TPD is being studied. It is likely that various causes including both physiological and pathological may be responsible for TPD. But very little is known about the mechanism that triggers partial to complete inhibition of synthesis of rubber and latex in the affected tissues.

The general contention is that when the capacity of a tree to regenerate the latex harvested through tapping becomes inadequate, the tree succumbs to TPD. This is largely based on the common observation that overexploitation of the trees either due to frequent tapping and/or chemical stimulation leads to increased incidence of TPD. Investigations do not indicate that a deficient supply of carbon source for rubber biosynthesis was a limiting factor in TPD affected trees, because key intermediates of the rubber formation were found in large concentrations in the affected trees. Therefore excess drain of photosynthates through latex may not be the primary cause for TPD.

The metabolic conversion of the precursors to the formation of rubber molecules is inhibited due to unknown reasons in TPD affected trees. Carbohydrates are known to accumulate in the latex even before the trees show symptoms of TPD indicating that inadequate availability of carbon was not the primary cause for TPD.

Several evidence suggested a relation between TPD and oxidative stress. Oxidative stress has been known to alter the normal metabolic pathways in a healthy tree by triggering a series of degenerative processes and may lower the respiratory activity and the energy status in the tissues. Conversion of intermediary metabolites to rubber is an energy consuming process and therefore this must be very sensitive to oxidative stress. Under oxidative stress, plants generally increases the production of free radical scavenging enzymes such as peroxidase, catalase, superoxide dismutase etc. and secondary metabolites like phenols melondialdehyde etc. In TPD trees these biomolecules were found in higher concentrations compared to normal trees. High peroxidases activity in TPD trees are capable of involvement directly or indirectly with several biological reactions including the regulation of plant growth regulators such as cytokinin, IAA, ethylene etc.

Cytokinins are an essential group of plant growth regulators which mainly maintain the juvenility and retard senescence. Therefore maintenance of high content of cytokinins are very essential for an active metabolic functions of the rubber tree tissue including active rubber biosynthesis. Investigations showed that the reduced content of a certain group of cytokinin in the bark tissue was related to TPD which fully inhibited the rubber biosynthesis. Similarly, the cytokinin content had an inverse relationship with peroxidase enzyme activity and phenol content. The rubber molecule formation requires three distinct biochemical process such as initiation, elongation and termination. The hydrophobic rubber molecule is packed inside a rubber particle and the polymerization reaction is taking place at the particle surface with the help of an enzyme rubber transferase, which is bound to the rubber particle. The particle size analysis in the latex showed differences related to TPD incidence in the rubber particles produced. The rubber particles, on an average become comparatively smaller towards the later stages of TPD. Analysis in the rubber transferase activity showed an inverse relation with the rubber particle size. Therefore in the TPD samples, the variation in the particle size can be directly related to the chain elongation processes which appears to be interrupted due to the relatively low availability of its immediate substrate in TPD trees. The latex sample of ethylene stimulated trees also showed similar changes in the particle size distribution which closely resemble the particle size of TPD trees.

It is important to investigate the exact molecular level mechanism by which the rubber biosynthesis is inhibited during TPD and the biochemical modulations occurring, if any, at the initiation, elongation and termination processes of rubber biosynthesis during the onset of TPD. Study of the energy metabolism in relation to the impaired rubber biosynthesis in the laticiferous tissues of TPD trees may help to identify whether there exist any limiting steps

involved in the energy utilization processes and the modulations occurring due to the action of growth regulators. This understanding is crucial to any attempts to overcome the disorder using any molecular biology techniques.

Studies were also initiated to understand the effect of rootstock on TPD and examined if bud grafting from a TPD-affected tree increases the chances of TPD. It was noted that the genetic distance between rootstock and scion tissues was greater in TPD affected than the healthy trees.

Investigations were shown that once a tree had shown TPD symptom in one tapping panel, it might easily develop this disorder in another panel. The reoccurrence of TPD in another panel of the tree indicates that TPD incidence is not a local phenomenon in the tree bark. This suggests either the involvement of a pathogen or the intrinsic susceptibility of the tree to the physiological disorder without any involvement of a pathogen. The randomness in the occurrence of TPD and the obvious failure to transmit the syndrome through grafting TPD affected bark on healthy trees and vice versa suggest the involvement of intrinsic factors rather than any pathogen. However, likely intrinsic differences in the ethylene production capacity or tissue sensitivity to ethylene between different trees within a clone could explain the random nature of TPD occurrence.

Through RAPD analysis, it was shown that the genetic distance between the rootstock tissues ranged from 7-39 % because of their heterogeneousness. Our results indicate that the genetic distance between rootstock and scion tissues was greater in TPD affected than in healthy trees. Investigations are on to find if a greater genetic distance between the root stock and scion is causing any kind of genetic conflict between them resulting in any subtle, but specific expressions in the scion.

The latex diagnosis (LD) can be used as a tool to predict overexploitation of the tree through over stimulation which may lead to TPD. Biochemical studies indicated that the concentrations of sucrose and Pi in the latex become higher in trees 15 to 45 days before the onset of TPD. Similarly, several investigations have pointed out that many types of proteins including heat stable proteins and LEA proteins are linked to TPD and all these are being used as putative protein markers for TPD/biotic stress in Hevea

Chapter 18

Management Practice to TPD

Giving tapping rest and changing the tapping panel are the generally followed plantation practices to manage TPD in rubber. Tapping rest does result in some improvement in the TPD situation at least for a while and a small proportion of the TPD trees may make full recovery particularly when the trees are reopened on a new panel. It is observed that most high yielding clones are highly susceptible to the disease and hence it would be advantageous to follow 1/2 S d/3 tapping system to reduce the intensity of exploitation stress thereby reducing the TPD incidence in the population. As a curative measure, resting the trees without tapping for a considerable period is advised. Therefore, tapping can be resumed changing the tapping panel and following a low intensity tapping system.

• Phanerogamic Parasites

Phanerogamic parasites, *Loranthus* and *Cuscuta* (Dodder) attack both rubber and cover crop *purearia phaseoloids* and *Mucuna bracteate*. *Loranthus* is a semi-parasite of tree trunks and branches and its leaves possess chlorophyll and synthesise carbohydrate but obtains water and mineral nutrients by growing haustoria into host tissue. *Cuscuta* is a non-chlorophyll bearing leafless, yellow thread-like twiner, appearing inter twining tangled mass. It is totally dependent on its host for food through haustoria penetrating into the host. Hence it causes more serious damage. The attacked part of the host becomes unhealthy and in severe cases dries off. At present, selective chemicals for control of these parasites are not available. Hence, the best remedy is to destroy them in the initial stage itself along with the host by cutting, removal and burning of attacked parts.

Chapter 19

Lightning Injury

Rubber trees of different ages are susceptible to lightning injury. The damage may be for a group of trees in lines or even in scattered pattern. The extend of damages varies.

The manifestation of visible symptoms of distress is rather sudden. Seriously affected trees are killed and they wilt in two to three days. Partial damage of some branches or portions of the main stem may also occur. In the affected portions, exudation of latex is observed and the bark separates from the wood and the damaged bark is colonized by borer beetles in large numbers. A characteristic feature is that cambium is the tissue that gets damaged first and as a result, cambium and the inner bark are coloured scarlet to dark violet. Death of tissues starts from the cambium extending through the bark in an outward direction. Soon after lightning strikes, incidence of patch canker also increases.

An assessment of the damage may be made as early as possible after the lightning strike, completely affected and dried up plants may be removed. In the case of partially affected plants, the damaged bark is scraped off, the exposed area washed, cleaned with Dithane (Indofil) M 45 0.75 per cent solution and after drying, a wound dressing compound applied. If exposed to hot sun, the treated portions may be whitewashed.

Fire Damage

A young rubber plantation with cover crop having a thick layer of dried up material underneath or a mature plantation with accumulation of dried up leaves following wintering becomes highly prone to fire damage during dry hot weather. Fire may originate from a neighbouring jungle or due to personal carelessness or by accident. The extent of damage varies from superficial scorching to deep injury of bark portions. Exudation of latex is often noticed. Colonisation of damaged bark by borer beetles and high incidence of patch canker are also observed following fire damage. Treatments to be undertaken are similar to that of lightning damage.

Sun-Scorch

Young nursery seedlings often suffer from sun-scorch. The bark at the collar region dries up resulting in a girdling effect and affected seedlings dry subsequently. This is mainly due to heating up of soil around the collar and could be prevented by mulching the nursery beds with dry organic matter by the advent of hot dry weather. Fresh green mulch should be avoided. In young seedlings, the bark at or above the collar region on the side facing south or southwest often gets damaged due to sun-scorch. In budded plants, sometimes, the dead snags of stocks fall off leaving a cavity at the bud union. When this faces south or southwest, sun-scorch effect becomes prominent and the bark on the scion dies. In this case, often the damaged bark is in the shape of a spearhead. The affected bark is colonised by wound parasitic fungi like *Diplodia* causing further damage. Care should be taken to avoid facing of budpatch to south or southeast direction while planting.

If untreated, sun-scorch affected plants may dry up or may be blown over by wind. In plants where the damage is not deep and extensive, the affected region may be scraped and washed with fungicide Dithane (Indofil) M 45 0.75 per cent solution and a thin coating of wound dressing compound applied. Above the treated surface, whitewashing of the stem from the collar upwards on the brown bark may be carried out using lime, during hot weather and this may be continued till the canopy closes. Once the canopy closes, only the border plants need be whitewashed. Provision of bamboo tree guards affording shade and mulching the plant bases with dry organic matter for young plants in the field will be helpful in reducing sun-scorch.

Chapter 20

Sprayers and Dusters

Owing to the presence of several ravaging diseases of rubber plants in Nigeria which causes considerable economic loss if left untreated, the possession or the availability of suitable plant protection equipment for planters

becomes imperative. For nurseries and young plants in the field for one or two years, a pressure retaining knap-sack sprayer and a hand rotary duster will be useful. For larger nurseries and holdings, a motorised knap-sack air-blast sprayer-cum-duster will be much more economical and convenient. For mature plants double action rocker sprayers will be necessary with bamboo extension lances. The effective coverage of rocker sprayers is only 0.4 hectare per day and hence one sprayer can command only about 15 hectares during one season. The sprayer after use should be cleaned well by pumping clean water through it. After the season's use, before storing, the sprayer may be serviced, lubricating wherever necessary.

For spraying oil-based, copper fungicide mistifier type sprayers are necessary. These are low volume sprayers in which strong air blast atomises fungicide droplets and blow to the surface to be sprayed. In immature areas, Microflex (Power Mobiles) Sprayer can be used to spray oil based copper oxychloride. This could also be converted to a duster and used for Sulphur dusting.

For spraying and dusting mature plants, a sturdy, powerful but easily portable sprayer-duster, has to be employed. Aspee Turblow tree duster-cum-sprayer and Skoda Microspray Power 400 are suitable for dusting as well as spraying operations. For effective operation and long life, these machines have to be handled carefully and serviced regularly.

- **Spraying and Dusting**

Spraying against fungal diseases, especially against abnormal leaf fall disease of rubber and shoot rot for young rubber in nurseries and fields is an annual feature which for effective execution in large areas calls for proper planning and mobilisation of equipments, men and materials. Care should be taken to use only good quality materials for preparation of Bordeaux mixture. Proprietary copper fungicides when stored for long periods deteriorate in quality and in some cases develop phytotoxicity.

In Bordeaux spraying, the mixture should be prepared correctly and used preferably on the same day itself. There should be at least a couple of hours of sunshine after spraying of mixture to dry up properly on the leaves. It is advisable not to spray when the leaves are wet. Both surfaces of the leaves along the petiole may be sprayed for obtaining maximum efficacy. The finer the particle sizes of the spray, the better the efficacy and hence a fine misty spray should be used. A coarse jet spray causes quite a lot of runoff of the fungicide and the resultant spray deposit will be poor and hence should be avoided.

In the case of Micron spraying, the fungicide oil mixture may be prepared in a ratio not less than 1:6. In order to ensure satisfactory protection during high rainfall conditions, it would be desirable to give two rounds of spraying using about 17 to 22 litres of mixture per round per hectare (1:6 proportion) with a gap of 10-15 days or single round of spray with about 30 to 37 litres mixture (1:5 proportion) depending on the planting material and age of plants, tree spread and foliage intensity. For highly susceptible clones like PB 86 and RRIM 600 two rounds of spray would be preferable. For immature rubber a single round with 17 to 25 litres would be sufficient. The machine has to be moved at a slow speed of about 2-3 km/hour preferably through the middle of two rows where the canopy has closed. However, in steep slopes and in widely spaced contour plantings it may become necessary to carry the machine along each row. In such cases also the machine should be moved far away from the tree bases. For optimum results spraying is to be carried out as close to the monsoon as possible.

Aerial spraying of rubber using copper oxychloride dispersed in diluent oil has now become an accepted practice. The results are generally satisfactory. However, missed patches of about 10 to 20% showing poor leaf retention still continue to pose a problem. For larger units this method of spraying is advantageous since it saves considerable time and many problems connected with other spraying techniques. For aerial spraying 8 kg of 56% oil dispersible copper oxychloride in 40 litres of spray oil is recommended per hectare of mature rubber.

Dusting operation against powdery mildew disease of rubber during the refoliation period should be started in the early hours preferably by 3.00 am and continued upto 11.00 am during which period the atmosphere will be still and the leaf surface will be wet due to dew formation in the night and dust will stick on leaves better. It is advisable to expose the sulphur to sun on the day previous to that of dusting so that it will be dry and free flowing. The sulphur dust should be of 325 mesh fineness. Bigger particle size will prevent the sulphur dust from rising to

the top of the plants and it is less effective in its fungicidal properties. Sulphur mixed with an inert material like talc in the proportion 70:30 is also effective.

Dusting should commence when 10% of the trees have refoliated. Depending on the refoliating pattern, prevailing weather conditions and the intensity of the disease, 3 to 5 rounds of dusting may be given using 11 to 14 kg per hectare per round, at weekly to fortnightly intervals. The machine may be moved at a slow pace on every 3rd or 4th row of rubber plants. One power duster can cover about 12 to 16 hectare per day normally. The labourers handling the sulphur should be given sufficient protection from inhaling the dust. To purchase, transport and stock pure sulphur, a permit from the District Collector and the Superintendent of Police is necessary. However, compound sulphur in the proportion of 70:30 does not come under this restriction.

Chapter 21

Some Useful Materials for Plantations

Note that these materials are not mostly use in Nigeria we are not going to explain everything here but only view.

- Acetic Acid
- Akomin
- Ammonia
- Bavistin
- Bordeaux Mixture
- Bordeaux Paste
- Brodifacoum
- Calixin
- Diluent Spray Oil
- Dithane (Indofil) M-45
- Ethrel
- Fenvalerate
- Formalin
- Formic Acid
- Lime Wash
- Malathion
- Metaldehyde (Meta)
- Oil Dispersible Copper Oxychloride
- Panel Protectant/Wound Dressing and Bark Renewing
- Phosjet
- Pidivyl
- Sevin
- Sodium Sulphite
- Sulphur
- Snail Kill
- Temik
- Thiride (wet)
- Tilt
- 2,4 D Acid (2.4 Di-Chlorophenoxy Acetic Acid)
- 2,4,5-T Acid (2,4,5-Tri-chlorophenoxy Acetic Acid)
- Zinc Phosphide

- **Contaf**
- **Roban**
- **Thimet**
- **Acetic Acid**

A good coagulant for latex. One litre of the acid will be sufficient for preparing 330 sheets of 500 g.

- Akomin

A systemic fungicide containing 40% phosphorous acid. A dilution of 0.08% is effective for black stripe disease control.

- vAmmonia

Used as an anticoagulant and preservative for latex. In shipments of concentrated latex ammonia content is adjusted to 0.7% as a preservative.

- Bavistin

2-methyl carbomyl benzimidazole 50% (BASF). A systemic fungicide. Use of 0.05% solution of the fungicide in water is effective against leaf spot diseases and powdery mildew disease in young plants.

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Bordeaux Mixture

One per cent mixture is effective against abnormal leaf fall disease. 1 kg copper sulphate, 1 kg quicklime in 100 litres water; dissolve copper sulphate in half the quantity of water in vessel, slake the lime and make up the half volume in another. Pour copper sulphate solution into the lime solution. Use copper, wooden or plastic vessels. Do not mix concentrated solutions and then dilute. Use the mixture the same day. Always filter the mixture to clogging of spray nozzles.

- Bordeaux Paste

Similar to Bordeaux mixture but more concentrated (1 kg in 10 litres) useful for protecting wounds, treatment of pink disease etc.. Not to be used on tapping panel.

- Brodifacoum

Single dose blood anticoagulant used as 0.005% a.i. bait either mixed in a food material like dried grains or as wax blocks.

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Single dose blood anticoagulant used as 0.005% a.i. bait either mixed in a food material like dried grains or as wax blocks.

- Lime Wash

Used for painting stem of plants exposed to sun to prevent sun-scorch. Better in effect than China clay. Applied in November-December every year till canopy shades the stem. Quick lime should be well burnt and slaked by adding water. Slaked lime is used for the lime wash.

- Sodium Sulphite

Used as an anticoagulant at a concentration of 0.05% in latex; excess retards drying of sheets and leads to tackiness on the surface of sheet.

- Sulphur

A fungicide used for the control of powdery mildew; the finer the particles of the powder, the better the fungicidal effects. Particles passing through 325 mesh is satisfactory. Should be dried and not to get lumpy. A mixture of 70% sulphur and 30% talc is equally effective in controlling powdery mildew. Useful for the control of mites also. Also widely used as vulcanising agent for rubber.

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Temik

A carbamate systemic insecticide sold as 10% granules. Useful for the control of slugs and snails, rodents and nematodes.

- **Zinc Phosphide**

Used for preparation of bait cakes or paste for the control of rats and other rodents. Cakes are prepared by mixing the poison with wax, sugar and flour in the ratio of 10:5:3:2. The wax is melted and other ingredients are added to it in small quantities and mixed thoroughly by continuous stirring. A few drops of coconut oil are added and the molten mixture is poured into paper rolls of diameter 0.5 cm with one end plugged and paper removed after cooling. Paste is prepared by mixing the poison with vaseline, sugar and flour in the ratio of 5:3:1:1. The mixing is done as described above and poured into foil tubes; bore the attractive food materials and charge them with the cake or paste. Extremely poisonous, warranting great care in handling.

- **Metaldehyde (Meta)**

A chemical used for controlling slugs and snails. Toxic to man and animals. Metabait is prepared by mixing Metadex, cement, lime and wheat bran (rice bran) in the ratio 2:3:5:16 by weight and the mixture made into a thick paste by adding water and made into small briquettes or pellets for broadcasting. Meta may be mixed with tapioca flour and cement to make a paste and painted at the base of plants. Spraying a one-day-old suspension of 0.5 or 0.1 % Meta in water on the ground area frequented by slugs and snails is very effective. A 40 % formulation of Meta marketed by M/s. Inkemex India Ltd. is "Metadex".

- **Formalin**

40% Formaldehyde used in dilute solutions as an anticoagulant; 0.02% on latex.

- **Snail Kill**

A proprietary product of M/s. Pesticide India sold as 2.5% metaldehyde bait pellets. Useful for the control of slugs and snail.

- **Contaf**

A Systemic fungicide - Common name teraconazole. Incorporated in wound dressing compound at 0.02% and used for control of dryrot.

-

- **Roban**

Chemical name is bromodiolone single dose anticoagulant used as 0.005% bait mixed in food materials or as wax blocks against rodents.

- **Thimet**

An organophosphorous granular insecticide common name phorate 10G used for control of cockchafer grubs. Broadcast 15 kg per hectare over seedbeds and sprinkle water.

- **Pidivyl**

Polyvinyl acetate compound used as binding and sticking agent of fungicides in Pink disease treatment marketed by M/s. Pareekh Marketing Pvt. Ltd., Mumbai.

- **2,4 D Acid (2,4 Di-Chlorophenoxy Acetic Acid)**

A hormonal substance used as a selective weed killer sold under various proprietary names. Effective against dicots and some monocots (water hyacinth), will harm rubber in higher concentration. Butylester or sodium salt of 2,4-D in 1-2% concentration in coconut oil and Prowax used as yield stimulant on rubber; causes less damage to bark than 2,4,5-T

Chapter 22

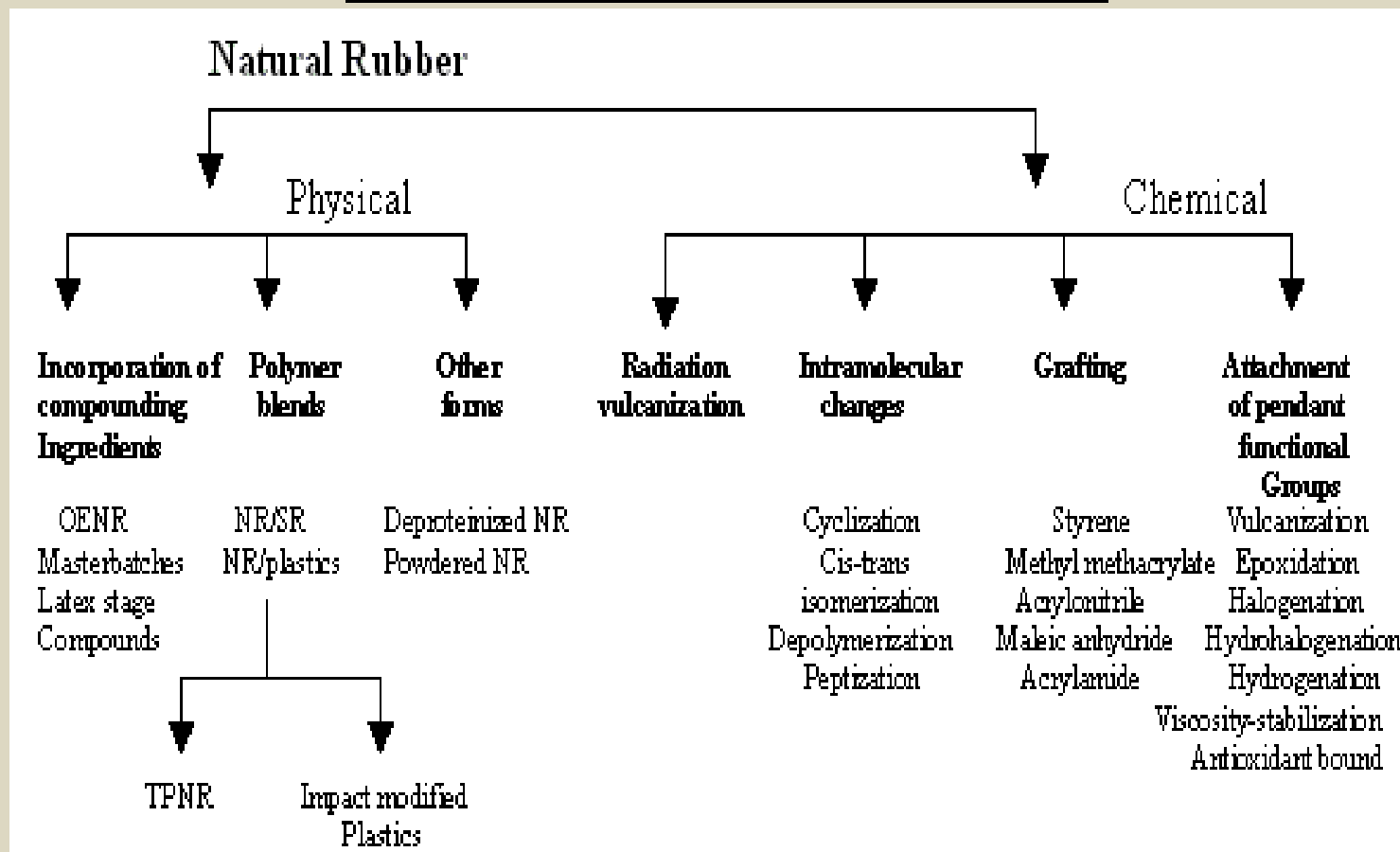
Properties and Uses of Natural Rubber

Natural rubber is a high molecular weight polymeric substance with viscoelastic properties. Structurally it is cis 1,4-polyisoprene. Isoprene is a diene and 1, 4 addition leaves a double bond in each of the isoprene unit in the polymer. Because of this, natural rubber shows all the reactions of an unsaturated polymer. It gives addition compounds with halogens, ozone, hydrogen chloride and several other reactants that react with olefins. An interesting reaction of natural rubber is its combination with sulphur. This is known as vulcanisation. This reaction converts the plastic and viscous nature of raw rubber into elastic. Vulcanised rubber will have very high tensile strength and comparatively low elongation. Its hardness and abrasion resistance also will be high when compared to raw rubber. Because of the unique combination of these properties, natural rubber finds application in the manufacture of a variety of products. The main use of natural rubber is in automobiles. In developed countries nearly sixty per cent of all rubber consumed is for automobile tyres and tubes. In heavy duty tyres, the major portion of the rubber used is NR. In addition to tyres a modern automobile has more than 300 components made out of rubber. Many of these are processed from NR. Uses of NR in hoses, footwear, battery boxes, foam mattresses, balloons, toys etc., are well known. In addition to this, NR now finds extensive use in soil stabilization, in vibration absorption and in road making. A variety of NR based engineering products are developed for use in these fields.

Specific gravity	0.92
Refractive index	1.52
Coefficient of cubical expansion	0.00062/°C
Cohesive energy density	63.7 Cal/cc.
Heat of combustion	10547.084 Cal/g
Thermal conductivity	0.00032 Cal/sec/cm/°C
Dielectric constant	2.37
Power factor (at 1000 cycles)	0.15-0.2
Volume resistivity	1015 ohm.cm
Dielectric strength	3937 V/mm

Chapter 23

Modified Forms of Natural Rubber



Physical Modification

Oil-Extended Natural Rubber (OENR)

Petroleum oils are used in rubber, either as a process aid or as an extender. When the oil added is below 10 parts per hundred rubbers it is termed as process aid and above that is termed extender, which cheapens the product. Natural rubber, which contains oil as an extender is termed oil extended natural rubber. In tyres OENR can impart high skid resistance on wet road, and resistance to wear and groove cracking. Oil addition to rubber can be carried out in latex or dry stage.

Latex Carbon Black Masterbatch

It is made by mixing carbon black in the form of dispersion in latex and the resultant rubber-black mixture is coagulated, dried and baled. Latex stage mixing of carbon black in rubber can save energy.

Thermoplastic Natural Rubber (TPNR)

Thermoplastic elastomers (TPE) are a new class of materials which possess the processing characteristics of thermoplastics and properties of vulcanised rubbers at room temperature. TPEs can soften reversibly with heat like thermoplastics, but possess considerable resilience and flexibility, a characteristic of vulcanised rubbers.

Thermoplastic natural rubber made from a blend of NR and polypropylene (PP) with certain definite composition can function as a TPE. The elastic properties of TPNR could be improved, with partial crosslinking of the rubber phase, known as dynamic vulcanisation. TPNR is generally resistant towards heat and ozone. TPNR may find application in

footwear, sports goods, automobiles etc.

Superior Processing (SP) Natural Rubber

Superior processing (SP) rubber consists of an intimate mixture of vulcanised and unvulcanised rubber. It is made by mixing vulcanised latex with preserved field latex in different proportions, followed by coagulation and drying. Typical grades are SP 20, PA 80 and PA 57. SP 20 – A blend that contains 20 parts vulcanised and 80 parts unvulcanised NR. It is available in sheet and crepe forms. PA 80 – A blend of 80 parts vulcanised and 20 parts unvulcanised NR. PA-57 – An oil extended version of PA 80. Superior processing rubbers find application in extruded products as it can reduce die swell, especially in lightly filled components.

Deproteinized Natural Rubber (DPNR)

DPNR is a highly purified form of natural rubber with very low nitrogen and ash contents. It is suitable for electrical and engineering applications. Removal of proteins from NR reduces its moisture sensitivity thereby improving its engineering properties. Deproteinization is usually effected by an enzymic means. Enzymes hydrolyse the proteinaceous non-rubber materials into water soluble forms, which are then washed away during subsequent processing.

Chemical Modification

Chemical Modification

Chemical modification of NR depends on the chemical reactivity of the rubber molecule. Different types of commercially relevant chemically modified forms of NR are shown below.

Chlorinated Rubber

It is one of the early forms of chemically modified NR which finds commercial application. Chlorination of NR is carried out in solution or in latex with gaseous chlorine. The chlorine content of the product is about 65 per cent. It is a pale cream coloured thermoplastic powder, which is non-flammable and highly resistant to chemicals. Chlorinated rubber finds application in paints, adhesives, printing inks, paper coatings and textile finishes.

Epoxidised Natural Rubber (ENR)

Though the mechanical properties of NR are superior to those of most synthetic rubbers, it cannot compete with speciality synthetic elastomers with regard to properties such as gas permeability and resistance to hydrocarbon oils. Latex stage epoxidation of NR under controlled conditions gives a chemically-modified form of NR, called epoxidised natural rubber (ENR) with improved resistance to hydrocarbon oils, low air permeability, increased damping and good bonding properties while retaining the high strength properties of NR. Improvement in these properties depends on the degree of epoxidation. Consequently two grades of ENR, ENR-25 and ENR 50 with 25 and 50 mole per cent of epoxidation respectively, have attained commercial importance. ENR can find application in products, which require, hydrocarbon oil resistance and air impermeability such as in oil seals and tyre inner tubes respectively. Another distinctive feature of ENR is the high degree of reinforcement achieved with silica fillers without the addition of a silane coupling agent. Silica reinforces ENR-25 and ENR 50 to an extent equivalent to that obtained with carbon black. Another interesting feature of ENR is its high wet grip and lower rolling resistance, which makes it a choice in tyre tread compounds. High bondability of ENR with other materials finds application in adhesives and sealants. Other general applications envisaged for ENR are in milking inflation, pharmaceutical and food contact applications, conveyor belting, shoe soles, floor covering, engine mountings etc.

Constant Viscosity (CV) and Low Viscosity (LV) Rubber

Natural rubber undergoes hardening or increase in viscosity during primary processing and subsequent storage under ambient conditions. This behaviour is termed 'storage hardening' and is enhanced by low relative humidity. The hardening occurs via a crosslinking reaction between the carbonyl groups randomly distributed on the rubber chain and the amino acids present in the non-rubber constituents. Storage hardening causes processing problems like consumption of higher energy. The hardening problem can be avoided by pretreating the latex with certain chemicals viz., hydroxylamine hydrochloride, hydroxylamine neutral sulphate or semicarbazide. Low viscosity rubber (LV) is a viscosity stabilized rubber added with a small quantity of naphthenic oil.

Chemical Modification by Grafting

Grafted natural rubber is a chemically modified form of natural rubber prepared by polymerising vinyl monomers onto natural rubber either in latex or in solution. Methyl methacrylate (MMA), styrene and acrylonitrile are the important monomers used for grafting on to NR. Generally grafting can be achieved using free radical initiation by two methods: by use of chemicals and by irradiation with gamma rays.

Poly (Methyl-Methacrylate) Graft Natural Rubber

It is produced by reacting methyl methacrylate monomer in NR latex with suitable initiators. A wide range of products is possible depending upon the amount of MMA monomer used for grafting. Malaysia have commercialised this product since 1950 under the trade name 'Heveaplus MG'. Three grades viz. MG 30, MG 40 and MG 49 are popular where the numbers represent the percentage of MMA content in the grafted rubber. PMMA grafted NR has higher modulus. It can provide self-reinforced vulcanisates. It finds use in adhesive and shoe industry.

Polystyrene Graft Natural Rubber (SGNR)

Polystyrene can be grafted onto NR by polymerising styrene in NR latex. Grafting can be initiated by chemical means or by gamma radiation. The SGNR could be used as a modifier in microcellular products.

NR Modification by Intramolecular Changes

Liquid natural rubber and cyclised natural rubber are the two commercially important modifications under this group.

Liquid Natural Rubber (LNR)

Extensive size reduction of the molecular chains of NR by depolymerisation leads to the formation of liquid NR.

LNR can be produced by thermal or chemical depolymerisation of NR. Thermal depolymerisation involves heating of the masticated NR at 220 to 240°C for a predetermined time under stirring, while chemical depolymerisation involves an oxidation – reduction reaction using phenylhydrazine and air.

LNR may find application in making flexible mould and printing industry and as binder for grinding wheels, reactive plasticizer in polymers etc.

Cyclized Natural Rubber

Cyclized rubber is a hard brittle thermoplastic derivative of NR obtained by treating NR with acidic catalysts such as sulphuric acid, aromatic sulphonic acids and lewis acids such as stannic chloride, titanium tetrachloride and boron trifluoride. A simple method of preparation is by mixing 100 parts of NR with 8 parts of para toluene sulphonic acid and heating the resulting mixture at 140°C. Cyclized rubber may find applications in adhesives, bonding agents, paints, shoe soles, hard mouldings, industrial rollers etc. and as a reinforcing resin.

Radiation Vulcanisation

Radiation vulcanisation is a new method for vulcanisation of rubber, especially latex with gamma rays, in the presence of a sensitizer namely normal butyl acrylate. The sensitizer is used to reduce the radiation dose. The advantages of radiation vulcanisation over sulphur vulcanization are the absence of n-nitrosamines, very low cytotoxicity and protein allergy. Radiation vulcanised latex can be used for the commercial production of gloves, condoms, catheters etc. In India, radiation vulcanisation plant with a capacity of 3 tonnes/day installed in Rubber Board is the only facility available for the production of vulcanised latex.

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References: Rubber India Board www.Rubberindiaboard.Org.In